Neutrons Reveal Secrets of "Gas Cages"

Opportunity

Gas hydrates are ice-like materials composed of water and gases, such as methane and carbon dioxide. They are made when water spontaneously forms molecular "cages" around gas molecules at high pressures and low temperatures. A better understanding of the kinetics and structure of gas hydrates may help researchers solve three major challenges.

1. **Developing a New Energy Source.** A large portion of the earth's methane is encapsulated as gas hydrates on the ocean floor (Figure 1) — these hydrates could be a plentiful source of natural gas if they can be safely and economically extracted.
2. **Combating Global Warming.** Scientists believe that some of the atmosphere's excess carbon dioxide can be sealed in carbon dioxide hydrates and stored on the ocean floor (where high pressures and low temperatures will keep them solid) as a way to reduce the earth's greenhouse gases.
3. **Improving Oil and Gas Delivery.** Gas hydrates are of interest to the oil and natural gas industries because the hydrates sometimes form and cause blockages in pipelines and equipment.

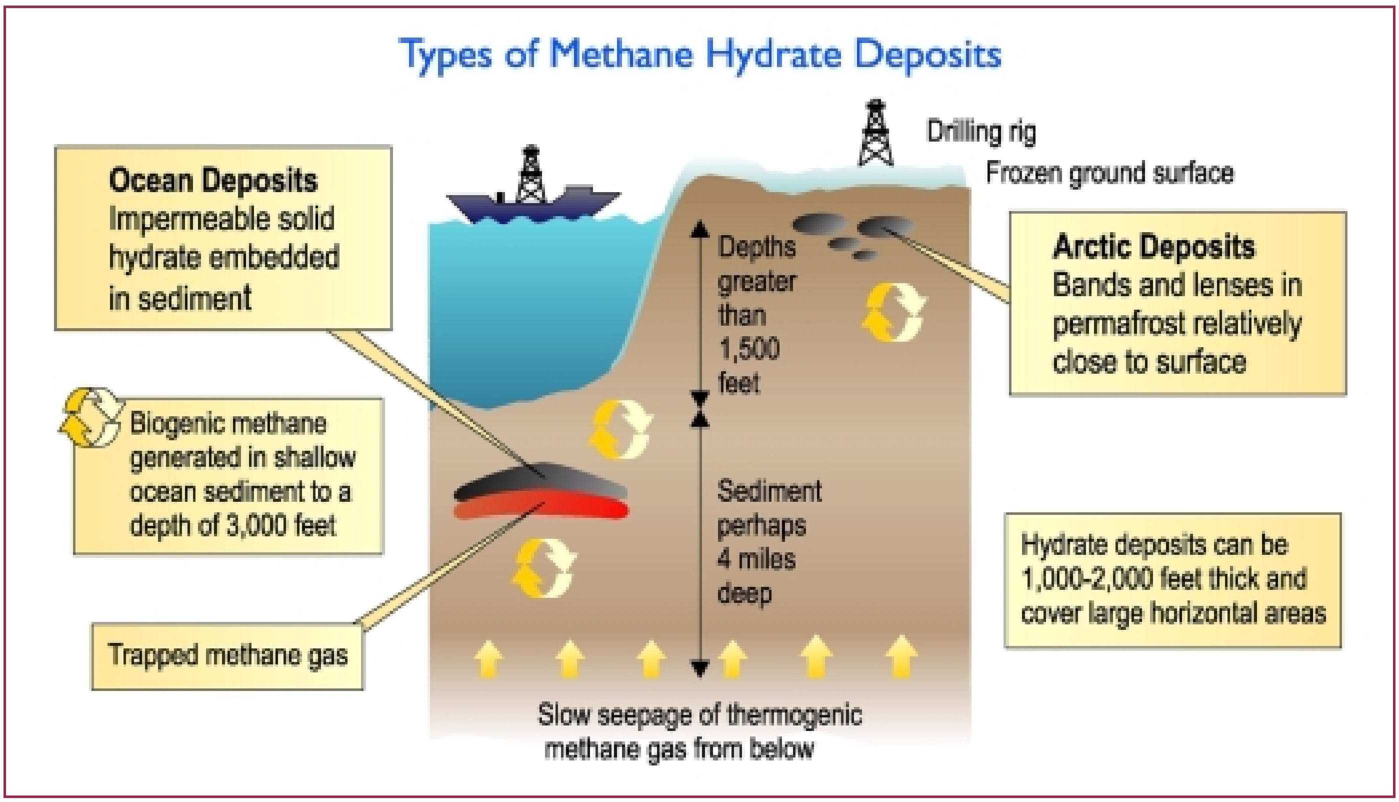

Figure 1. Diagram showing types of methane hydrate deposits.

Argonne's Solution

In order for us to be able to use hydrates, we need to understand how fast and under what conditions they form and decompose, how stable they are, and at what point the crystals begin to stick together. This is where neutrons come in. When neutrons — uncharged particles found in nearly all matter — scatter from a sample, their direction and speed reveal structural and dynamic properties that can provide scientists with a better understanding of the material's behavior.

Using the Intense Pulsed Neutron Source (IPNS) — one of the world's most productive sources of neutrons for materials research — Argonne has provided new insights into the formation and properties of carbon dioxide and methane hydrates.

Approach

Argonne scientists used time-of-flight neutron powder diffraction to observe the rates, or kinetics, of the formation of carbon dioxide hydrates from ice (Figure 2). By performing this measurement at several different temperatures, the research team determined the amount of energy needed to activate the formation process.

Scientists used liquid nitrogen to freeze deuterated water (water made with an isotope of hydrogen containing one proton and one neutron in its nucleus; plain hydrogen, which contains only a proton, causes interference in the instrument). Then the ice was ground to a fine powder, placed in a cooled aluminum cell, and lowered into the High-Intensity Powder Diffractometer at the IPNS. Under a barrage of neutrons, carbon dioxide gas was piped into the sample cell under high pressure.

Unlike x-rays and other forms of light, neutrons can more easily penetrate both the aluminum cell and the ice crystals, providing a series of snapshots as the ice restructures itself around the carbon dioxide molecules.

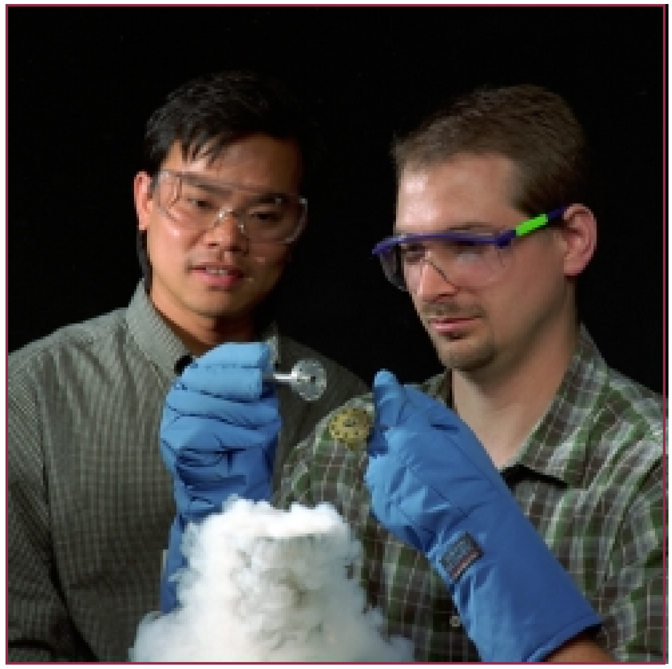

Figure 2. Argonne researchers prepare a sample chamber for gas hydrate research.

Results and Future Plans

The reaction proceeded according to the well-known "shrinking core model," which describes many reactions, including that of concrete as it sets. The data hint at the mechanism by which the water molecules arrange themselves around the carbon dioxide molecules. It seems to occur at a quasi-liquid, "pre-melt" surface layer of water molecules. This layer is slightly organized, but it has neither the random movement of water nor the crystal lattice of ice.

Future projects include varying the ice grain size, pressure, and type of gas molecules. Preliminary tests are under way with argon and methane.

Impact

This information, and future data, will be valuable in determining practical applications for gas hydrates.

Sponsor

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